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Wideband Photometric Magnitude Measurements of Saturn Made During the 2005-06 Apparition

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WIDEBAND PHOTOMETRIC MAGNITUDE MEASUREMENTS OF SATURN MADE DURING THE 2005-06 APPARITION

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ABSTRACT

The writer made 37 brightness measurements of Saturn + rings between Nov. 3, 2005 and March 16, 2006 using the B (blue), V (green), R (red) and I (infrared) filters. The selected normalized magnitudes of Saturn at a ring tilt angle of 18° are: B(1,0) = -8.43±0.03, V(1,0) = -9.48±0.02, R(1,0) = -10.16±0.04 and I(1,0) = -10.28±0.02. The selected phase angle coefficients of Saturn, in magnitudes/degree, are: c_B = 0.022±0.014, c_V = 0.021±0.008, c_R = 0.027±0.015 and c_I = 0.018±0.011.

Key Words: Saturn, Magnitude, Ring Brightness, Opposition Surge

INTRODUCTION

During late 2005, summaries of two important Saturn studies were published. French and co-workers (1) analyzed Hubble Space Telescope images of Saturn made between 1996 and 2004 and report that Saturn's rings have an opposition surge. The opposition surge is a sharp brightness increase that occurs when an object reaches opposition and is thus in the opposite direction of the Sun as seen from Earth. Salo and co-workers (2) carried out a theoretical study of the opposition surge data of Saturn's rings in visible light and they conclude that most of the B ring's opposition surge is due to a reduction of shadowing of one particle on another. Therefore, these studies show that Saturn's rings become much brighter at opposition. The current study is a continuation of a long-term photometric study of Saturn + rings that began in 1991; the aim of this study is to measure Saturn's brightness/color and its opposition surge in 2005-06. This long term study will help in understanding: 1) whether Saturn undergoes seasonal brightness changes, 2) the nature of Saturn's rings and 3) long term (1-3 decade) changes in the brightness of Saturn's rings.

METHOD AND MATERIALS

The writer used an SSP-3 solid-state photometer along with a 0.09 meter Maksutov telescope and filters that were transformed to the Johnson B, V, R and I system to make all brightness measurements. More information on the equipment can be found elsewhere (3, 4). Magnitude measurements were carried out in the same way as in Schmude (5). All magnitude measurements were corrected for both atmospheric extinction and color transformation. Color transformation corrections were made in the same way as is described in Hall and Genet (6). The comparison star for all measurements was iota Geminorum; the magnitudes were taken from Iriarte et al. (7). The check star was epsilon-Tauri; the measured magnitudes for this star were B = 4.50 ± 0.02, V = 3.55 ± 0.02, R = 2.85 ± 0.02 and I = 2.31 ± 0.01. The V and I measurements are close to the literature values; however the B measurement is 0.04 magnitudes brighter than the literature value and the R magnitude is 0.05 magnitudes fainter than the literature values. These discrepancies may be due to the low number of check star measurements made; nevertheless, as a result of these discrepancies, I have increased the uncertainties of the B(1,0) and R(1,0) values to 0.03 and 0.04 magnitudes respectively.

RESULTS

All magnitude measurements are listed in Table I. Columns 1, 2 and 3 list the date in Universal Time, the filter used and the ring tilt angle as seen from Earth. The ring tilt angle is the angle between the ring plane and a line defined by the centers of the Earth and Saturn and it has the symbol of B. The solar phase angle and the measured magnitude values are listed in the fourth and fifth columns. The solar phase angle of Saturn is the angle between the Sun and the observer measured from Saturn. The normalized magnitude, $X(1, \alpha)$ at a ring tilt angle of 18°, is listed in the last column in Table I, $X(1, \alpha)$ is computed from:

$$X(1,\alpha) = X_{mag} - 5.0 \log[r \times d] - 2.5 \log[k] + \Delta m(18°) - \Delta m(B) \quad (1)$$

where α is the solar phase angle, $X(1,\alpha)$ is the normalized magnitude at a solar phase angle of α, X_{mag} is the measured magnitude for filter X, r and d are the Saturn-Earth and Saturn-Sun distances in astronomical units, k is the fraction of Saturn + rings that is illuminated by the Sun as seen from the Earth; k is computed from:

$$k = (1 + \cos \alpha)/2. \quad (2)$$

Table I: Magnitude Measurements of Saturn.

Date (UT)	Filter	Ring Tilt Angle (degrees)	Solar Phase Angle (degrees)	Measured Magnitude	Normalized Magnitude X(1,α) B = 18°
Nov. 3.403, 2005	V	17.5	6.3	0.25	-9.35
Nov. 3.414	B	17.5	6.3	1.33	-8.26
Nov. 3.425	R	17.5	6.3	-0.42	-10.02
Nov. 3.435	I	17.5	6.3	-0.59	-10.18
Nov. 18.416	V	17.4	6.0	0.18	-9.35
Nov. 18.430	B	17.4	6.0	1.29	-8.24
Nov. 18.444	R	17.4	6.0	-0.49	-10.02
Nov. 18.460	I	17.4	6.0	-0.63	-10.17
Nov. 30.313	V	17.5	5.6	0.11	-9.38
Nov. 30.328	B	17.5	5.6	1.12	-8.36
Nov. 30.340	R	17.5	5.6	-0.52	-10.01
Dec. 12.269	V	17.6	4.7	0.08	-9.37
Dec. 12.292	B	17.6	4.7	1.10	-8.34
Dec. 25.287	R	17.9	3.7	-0.69	-10.08
Dec. 25.301	I	17.9	3.7	-0.85	-10.25
Dec. 25.315	V	17.9	3.7	-0.04	-9.43
Dec. 25.327	B	17.9	3.7	1.04	-8.36
Jan. 3.233, 2006	R	18.1	2.8	-0.70	-10.07
Jan. 3.248	I	18.1	2.8	-0.86	-10.23
Jan. 9.157	R	18.3	2.2	-0.74	-10.09
Jan. 9.172	I	18.3	2.2	-0.87	-10.22
Jan. 9.185	B	18.3	2.2	0.99	-8.37
Jan. 10.247	V	18.3	2.1	-0.07	-9.42
Jan. 10.243	B	18.3	2.1	0.98	-8.37
Jan. 25.208	V	18.8	0.340	-0.22	-9.55
Jan. 25.222	B	18.8	0.338	0.80	-8.53
Jan. 26.167	V	18.8	0.230	-0.24	-9.56
Jan. 26.184	B	18.8	0.229	0.77	-8.56
Jan. 26.207	R	18.8	0.226	-0.85	-10.17
Jan. 26.225	I	18.8	0.224	-1.08	-10.40
Feb. 1.194	V	19.0	0.502	-0.17	-9.49
Feb. 14.134	V	19.4	2.0	-0.12	-9.45
Feb. 14.147	B	19.4	2.0	0.96	-8.37
Feb. 16.188	R	19.5	2.2	-0.82	-10.14
Feb. 16.195	I	19.5	2.2	-0.94	-10.26
Mar. 16.165	R	20.1	4.9	-0.59	-9.97
Mar. 16.175	I	20.1	4.9	-0.78	-10.16

Finally $\Delta m(18.0°)$ and $\Delta m(B)$ are the magnitude changes caused by the rings at ring tilt angles of 18.0° and B; the Δm values are computed from the equations in Schmude (11). The necessary Saturn-Earth and Saturn-Sun distances, ring tilt angles and solar phase angles were taken from the Astronomical Almanac (8, 9). Solar phase angles below 1.0° were computed from the Jet Propulsion Laboratory (JPL) ephemeris generator (10).

The X(1,0) values and solar phase angle coefficient values for each of the four filters were computed in the same way as in Schmude (5); the results are summarized in Table II. The X(1,0) value is the normalized magnitude extrapolated to a solar phase angle of 0°; the solar phase angle coefficient shows how quickly Saturn and its rings dim as the solar phase angle increases.

Table II: Photometric Constants of Saturn + Rings measured during the 2005-06 Apparition.

Filter	X(1,0)	c_x
B	-8.43 ± 0.03	0.022 ± 0.014
V	-9.48 ± 0.02	0.021 ± 0.008
R	-10.16 ± 0.04	0.027 ± 0.015
I	-10.28 ± 0.02	0.018 ± 0.011

DISCUSSION

Figure 1 shows the V-filter normalized magnitudes of Saturn made between 1995 and 2006 as a function of the sine of B, where B is the ring tilt angle in degrees. The solid line is the best fit of the 1995-2002 data (11). The agreement between the 1995-2002 trend and the 2003-2006 points is good.

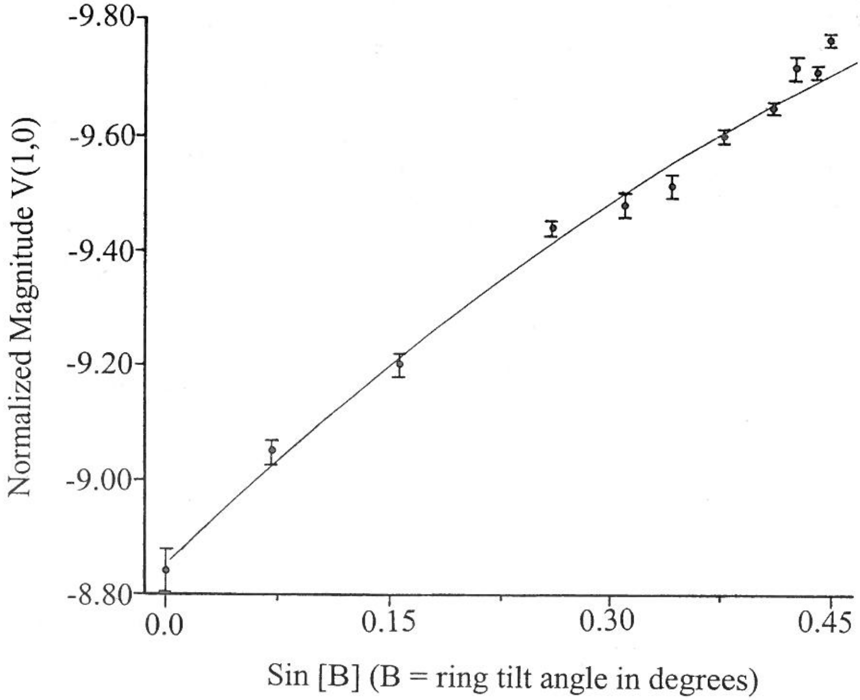

Figure 1: Saturn's normalized magnitude plotted against the sine of the ring tilt angle.

The solar phase angle coefficients in the V-filter as a function of Sine [B] are plotted in Figure 2. The data suggests that the solar phase angle coefficient of Saturn + rings drops with decreasing ring tilt angle; this trend may be due to the fact that the rings contribute less light as B drops. Data in the next three years are needed to confirm the trend in Figure 2.

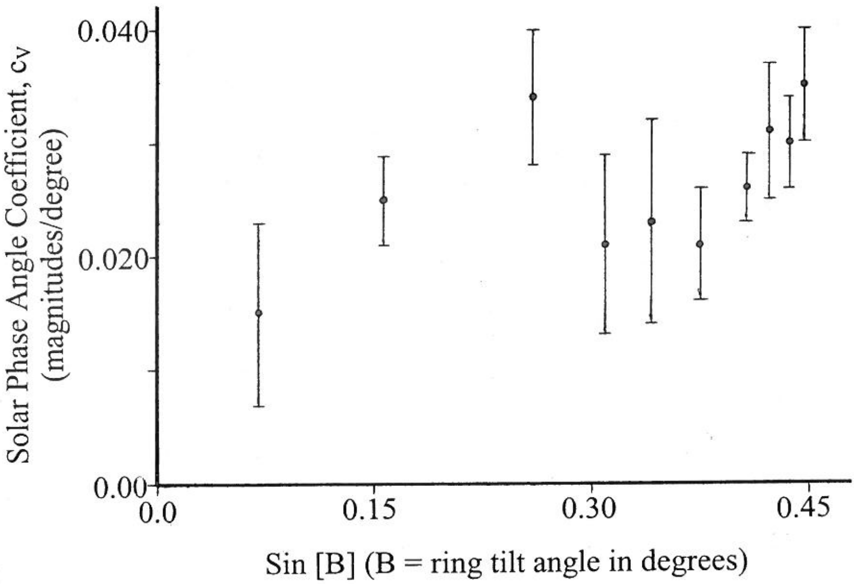

Figure 2: Saturn's solar phase angle coefficient (in the V-filter) plotted against the sine of the ring tilt angle.

Opposition surge values were computed in the same way as in Schmude (5) and are listed in Table III. The opposition surge values are similar to those in 2004-2005 (5).

Table III: Opposition surge measurements of Saturn + rings in Jan. 2006.

Filter	Solar Phase Angle (degrees)	Date (2006)	$X(1,\alpha)$	Opposition Surge (magnitudes)
V	0.340	Jan. 25	-9.55	0.08
B	0.338	Jan. 25	-8.53	0.11
B	0.229	Jan. 26	-8.56	0.14
V	0.230	Jan. 26	-9.56	0.09
R	0.226	Jan. 26	-10.17	0.01
I	0.224	Jan. 26	-10.40	0.12
V	0.502	Feb. 1	-9.49	0.02

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